MIFACE Investigation Report #10MI069

SUBJECT: Hispanic Farm Laborer Electrocuted in Potato Field

Summary

In the summer of 2010, a Hispanic male farm laborer in his 20s was electrocuted in a potato field when he touched the energized cross-brace of an operational self-propelled irrigation system while pulling free growing corn. He was standing in pooled water. One of his two coworkers heard the decedent yell. The coworker looked back and saw the decedent leaning with his left arm on the tower cross brace between the tires. The decedent then fell to the ground. The coworkers called their supervisor at the farm. The farm office called for emergency response and turned the irrigation system off. The decedent was declared dead at the scene. After the incident, the irrigation unit and wiring were examined by multiple firms. The system could not be restarted for inspection. The investigation found that the irrigation system was properly grounded and that underground wires supplying power were "burned off" in four places, thought to be consistent with a lightning strike. A definitive determination could not be made as to how the electrocution occurred.

Figure 1. Irrigation unit involved in incident.

Contributing factors:

- Age of underground wiring
- Direct burial of wiring without the protection of conduit to avoid damage to wiring insulation from stones and frost heaving
- Working in field while irrigation equipment operational
- Weather, including undetected electrical storm damage
- Electrical inspection not performed

RECOMMENDATIONS

- Ensure irrigation system wiring and grounding is continuous and in accordance with the American Society of Agricultural Engineers Standard S362 and Article 675 of the National Electric Code.
- Farmers should implement an electrical inspection program for irrigation equipment at the beginning of each season that includes periodic inspections of all system components throughout the growing season. This inspection should include checking the integrity of the underground wiring associated with the system.

- When installing new underground wiring for irrigation systems, farmers should install the wiring in PVC conduit to protect the wiring insulation.
- General agricultural workers should be prohibited from working in a field area which is under active irrigation; however, manufacturing and trained service and maintenance workers may have to do work with operational irrigation units.
- In areas of high levels of lightning activity, farmers should consult with the irrigation system manufacturer to determine if installing lightning arrestors on the central pivot will provide additional protection for their equipment.

BACKGROUND

In the Summer of 2010, a 28-year-old Hispanic male farm hand was electrocuted in a potato field when he touched the energized support bar of an operational irrigation tower while pulling free growing corn. MIFACE was notified of this incident through the MIOSHA 24-hour hotline. MIFACE contacted the farm employer and an on-site interview was conducted with persons familiar with the incident details. During the writing of this report, the police report and pictures, death certificate, and MIOSHA file were reviewed. The pictures used in this report are courtesy of the responding police department and the MIOSHA compliance officer.

Figure 2. Center pivot involved in incident.

The decedent's employer (Farm 1) farmed approximately 6000 acres of potatoes. The potato field and the irrigation equipment were leased from another farm owner (Farm 2). Fifty-two individuals were employed on the decedent's employer's farm operation. The decedent had worked for the farm owner for approximately one year. The decedent was paid hourly. The workers were not represented by a union. The decedent was bilingual (English and Spanish) and was designated as the lead person in the field. The farm did not have a farm safety plan or written procedures for working in the field when either of the two irrigation systems were operational. Workers were provided on-the-job training in Spanish when that was their primary language.

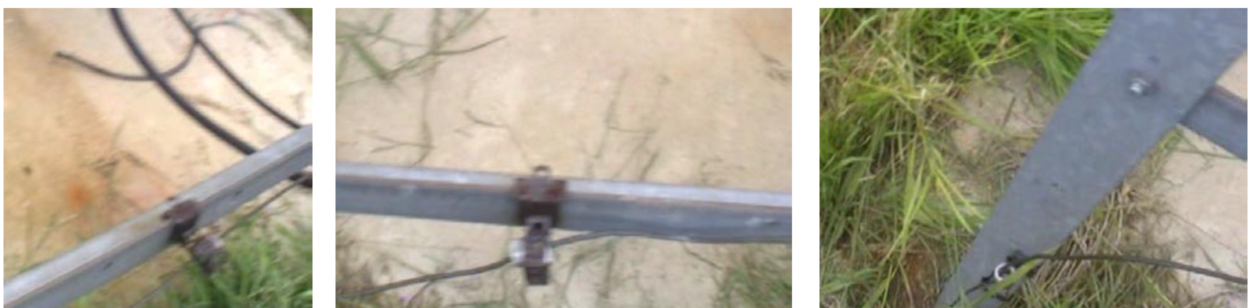
Figure 3. Power supply to Valley Pivot. Valley Pivot plugged into receptacle.

The potato field was irrigated by two center pivot self-propelled Valley and Reinke (Electrogator-Reinke Model 6356 irrigation systems. The Valley pivot was referred to as the South Pivot. The Valley pivot and the electrical box had been installed at least twenty years prior to the incident. The Reinke system was referred to as the North Pivot. It had been installed several years before the incident and was maintained by a local farm supply company (Firm A).

The main power to both center pivot irrigation systems was located in the southeast corner of the field. The irrigation systems utilized a 3-phase, 480-volt electrical system with one of the phases being the ground. The main box had a disconnect panel. An underground power cable from the electrical box traveled several hundred yards to the Valley center pivot.

Figure 4. Machine ground of Reinke central pivot.

The underground wiring continued from the Valley center pivot to the Reinke center pivot. Each pivot had a disconnect panel and a ground rod. Each pivot also had a separate ground wire that traveled horizontally away from the pivot. The central pivot systems distributed water to each single-leg tower through an 8- to 10-inch water pipe located approximately 10 feet above the ground.



Figures 5-7. Path of Reinke ground wire.

The electrocution occurred at the seventh single-leg tower associated with the Reinke center pivot. Each tower section consisted of two frames that each ran down to a rubber drive wheel connected with a horizontal frame piece running horizontally between the wheels about 45 inches above the ground. There was an enclosed drive motor located centrally on the horizontal frame piece which powered the drive shaft. The motor was connected to a junction box and grounded, which was rated for wet locations mounted on top of the 8- to 10-inch pipe water supply pipe.

Figure 8. Machine ground of Reinke unit to ground stake.

Both pivots could be remotely activated from the Farm 1 main office location.

At the conclusion of the MIOSHA General Industry Safety and Health Division investigation, the Division did not issue the farm a citation of violation of a MIOSHA Safety/Health standard.

Firm Remediation

After the incident, the decedent's employer made it a policy to conduct an electrical inspection program at beginning of the growing season.

INVESTIGATION

Firm A had recently been at the field performing maintenance on the incident irrigation tower. The maintenance person changed the wheel gear box (where the pivot folds and starts to move in a different direction). It was the last wheel gear box on the pivot system. This was the same area where the decedent was thought to be standing when he was electrocuted. The owner of Firm A stated that the employee had tested the end gun and had checked the pivot and had indicated it seemed to work fine. Firm A did not change the motor or perform any other electrical work on the tower.

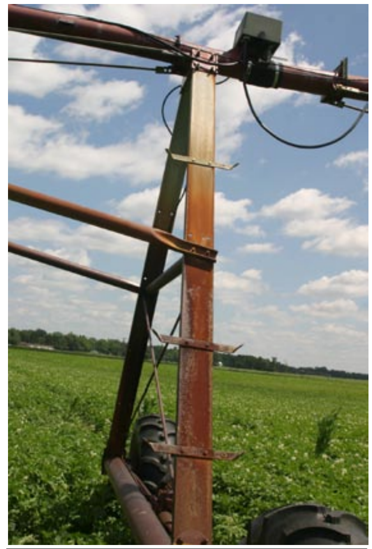


Figure 9. Incident irrigation tower.

The decedent, who was bilingual, and his coworkers, who spoke only Spanish, arrived at the field at approximately 8:30 am. They began the process of clearing the free growing corn from the potato field. Each worker was clearing an area of 80 rows. The police report indicated that the crew worked on the south half of the field in the morning and finished that section. Then they began to work on the north half of the field. They had taken a 15-20 minute lunch break at approximately 11:56 a.m. and had returned to the field after finishing lunch. They were traveling south in the field as they continued to pull corn.

At approximately 1:30 p.m., the irrigation system was remotely activated and the activation was logged as being turned on. A thunderstorm with lightning was NOT present within 50 miles of the incident site. Therefore, a "bolt from the blue" was not a factor in this incident.

Figure 10. View of Valley and Reinke irrigation units. Reinke Center pivot would be located to the left of the tower.

The police report indicated that one of the decedent's coworkers (Coworker 1) was working ahead of and between Coworker 2 and the decedent. Coworker 2 was to short distance behind and to the west of Coworker 1. The decedent was positioned east of Coworker 1 and was further behind Coworker 2. As the three workers approached the overhead irrigation system, the decedent told them to just hurry and try to get ahead (pass) of the irrigation system. Coworker 1 and Coworker 2 had moved ahead of the irrigation system. The decedent was still working behind them. The workers were soaking wet and working in standing water and muddy conditions.

Coworker 1's statement to the responding police indicated he heard the decedent yell, but thought he was just starting to sing out loud. About three or four seconds after the decedent yelled, Coworker 1 turned around and saw that the decedent leaning against the tower bar that connected the tires of the irrigation system with his body weight on his left forearm; he was not slumped over, his feet were touching the ground and his head was still somewhat erect. Coworker 1's statement indicated he thought something was wrong with the decedent; that he was ill and was just resting on the bar. Coworker 1 got the attention of Coworker 2. Both walked toward the decedent and found that he was not moving and did not look normal. As they got closer, Coworker 1 began to think that the decedent might have had a heart attack. When they were approximately 10-15 feet away from the decedent, Coworker 2's statement to the police indicated that he thought that the decedent had been electrocuted, so the two workers did not move any closer.

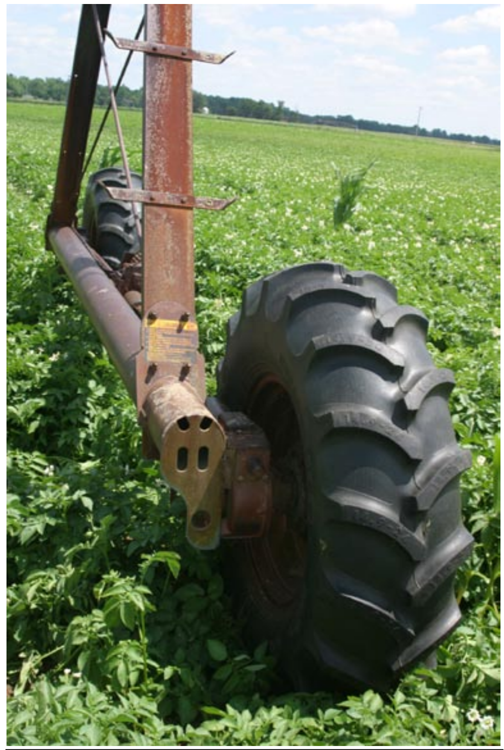


Figure 11. Close view of the base of the incident irrigation tower.

Coworker 1 told Coworker 2 to call Farm 1's main office. The call was made at 2:49 p.m. A bilingual individual at the office received the call and was told by Coworker 2 that someone should come to the field to check on the decedent because he had fallen on the pivot and was no longer moving. The office worker told Farm 1's owner (decedent's employer). The owner immediately called 911, got into his truck, and drove to the field where he met the ambulance. The irrigation system continued to function during this time. The tower moved, causing the decedent to fall to the ground. The decedent was found lying on the ground approximately 20 feet from the tower.

Another farm employee arrived, and the owner called to this employee and instructed him to turn off the power to the Reinke irrigation pivot in case electrocution was the cause of the incident.

The MIFACE researcher checked the weather for the cities within 20 miles of the incident site to determine if lightning was present; weather was clear and there was no lightning present.

Post Incident Investigation

After the incident, the decedent's employer contacted the farm supply company that had installed the system (Firm A) and an electrician with a local company (Firm B), who was hired by the decedent's employer as a third party consultant. Farm 1's insurance company contacted an electrical consulting company (Firm C). Working together, the three firms attempted to ascertain the cause of the electrocution.

The written report of Firm B to Farm 1's owner is contained within the quotation marks below. The MIFACE investigator, to maintain the anonymity of the firms, has substituted the firm names and referenced dates in the report.

"Our first goal was to re-energize the unit and safely measure voltages to see if any voltage was present on the frame of the unit. While re-energizing the unit, it was discovered that a fuse was blown at the main service in the electrical disconnect that fed power to both pivots. The underground wires pass through the disconnect located at the valley pivot at the south end of the field before the wires extend to the Reinke Pivot. The Reinke pivot is the unit where the incident happened. Power was present at the main service disconnect, but no voltage was present at the first disconnect located at the Valley unit. Upon investigation, it was determined that the problem was in the underground wires between the main disconnect and the Valley Unit.

Being unable to restore power to the Reinke unit, we discussed how the underground wire could be connected to what had happened. As we talked, we determined that this pivot had only run for a matter of hours since the last big storm that had come through the area the previous weekend. Underground wires being damaged by lightning is a very common problem with these systems. It is feasible for the wires to carry power for a while before failing. There is one other possibility that could have allowed this to happen. We discovered that the farmer maintaining the system for the owner of the field (Farm 2) had been using the well to fill water tanks the evening of the incident. While this was taking place, the underground wires were re-energized. With power present on the underground wires, they could have finished burning out from the lightning damage.

We started inspecting the actual Reinke unit. We located the ground rod and grounding wire at the main control panel on the unit. It was connected to the ground rod and all equipment grounding wires in the control panel were bonded in the same location to the grounding conductor by mechanical means. The wires entering the panel go through a disconnect switch located about 20 feet away. We traced the cables that leave the control panel up to the top of the unit. There is a smaller control box located on each tower which feeds the motor on each individual tower. These cables pass through each control box onto the next one. The incident happened at the 7th tower. We opened up the box and motor on that tower and inspected all of the wiring thoroughly. It was confirmed that all of the grounding wires were in fact connected. We did not find any problems with this system.

Next we went back through the field inspecting the wiring and all electrical boxes at both pivot panels and at the main service/pump panel. Overall, the Reinke unit is not that old and seemed to be in relatively good shape. The electrical wiring seemed to be sound. The wiring throughout the rest of the field was older. Some of it was not in the best condition. Some of the items found were wires doubled up under lugs in the disconnect switches. The cord, plug, and receptacle feeding power to the Valley unit were in bad shape. The very first disconnect switch feeding power to the pivots had 50-amp fuses, which were oversized. The fuses at the pivots were the proper size. None of these items individually appeared to be significant safety issues. We made note of these items and they were repaired before power was restored.

The one thing we did find was that the incoming electrical power from the utility company is a 480-volt, 3-phase ground delta system, meaning that one of the three phases is intentionally grounded. The proper voltage reading from phase to phase is 480 volts, phase to ground on the two ungrounded conductors should be 480 volts and phase to ground on the intentionally grounded leg should be 0 volts. These are the voltages that we measured. We noticed that there was a solid bar in the main 200-amp disconnect which is proper for this application. Also noticed were fuses present on the intentionally grounded leg throughout the rest of the wiring feeding through to the pivots.

Firm A had located a problem area in the underground wires. It was decided that they needed to wait to dig it up.

The owner of Farm 1 and Firm B met with a professional engineer from Firm C. The professional engineer was sent from Farm 1's insurance company to conduct an investigation of the electrical system. As a group, we went to the field where professional engineer started at the main electrical service and inspected the entire electrical system. He took voltage readings, and pictures and used a "megger" to verify wire and component integrity. We went from the main panel to the Valley Pivot and ended up at the Reinke Pivot using the same procedure throughout the process with the exclusion of the underground wires because of their damage. We spent quite a bit of time on the Reinke unit both in the control panel and out at the tower section.

At this juncture, we brought in a generator and restored power to the Reinke unit bypassing the underground wires. While running, we safely tested the system to ensure it was running properly, which it was. Voltage readings were then taken on the metal sections of the unit and measured for voltage to ground. This was performed at multiple areas of the control panel and out on the towers. During this testing, there was never any voltage present.

Meanwhile the Firm A employees had exposed multiple locations where the underground wires had been damaged. The wires were dug up but not yet repaired. They all appeared to be standard lightning damage sections. At the end of the day, the professional engineer noticed that it appeared one of the lightning arrestors on the power company's pole where the transformers were located was blown apart. I reported it to the power company. The lineman looked at it that evening and called me to confirm that it appeared to be damaged from lightning. They repaired it the next day.

Reinke recommendations for a grounded delta system – they recommended a solid bar be put in the place of all fuses in the intentionally grounded phase. The electrical inspector summoned by Firm C agreed this is what should be done.

The underground damaged wires were repaired by Firm A. We added additional ground rods at both pivots and bonded the main electrical service to the metal well casing. The systems were grounded previously, but these extra steps provided a better grounded system and help to protect against lightning. We replaced a few sections of wiring and installed new fuses where needed.

When the sections were repaired we "megged" the wires to test the integrity of the wires/repairs. The wires did not read well at all. We did turn the power back on to the entire system and did measure 480 volts out at the Reinke Unit. When we turned the unit on it ran correctly. Again we have the grounded Delta system present. Reading should be 0 volts to ground on the "B" phase. The distance from main service to the Reinke system is very long and there are voltage drop concerns with this distance. The wires were oversized to allow for this. Due to this there is resistance on the wire and there will be a low voltage reading present on the "B" phase. The voltage readings we were measuring were excessive. Readings were up to 30-volts on the “B” phase with unit pulling only 6 amps. While running, I measured for any voltage present on the metal structure. There was no voltage present on the system despite the high “B” phase voltage readings.

It was decided that the underground wires would need to be replaced completely. The system was locked back out until this could happen. Farm 1 would use a generator to run the system in the meantime. We were not able to find anything wrong with the Reinke system itself.

Several weeks later (*exact date removed for anonymity*) the new underground wires were installed. Firm B assisted Firm A with the installation. We did “megg” the new wires on the reel prior to installing them. The wires show the best reading possible. We “megged” the wires a second time, after they were installed in the ground. Again, they showed perfect readings. Power was restored and voltage tested at both pivots. This time the largest voltage we read on the “B” phase was around 10-volts with up to 14 amps, which is typical or a little better than usual for the distances of wire.

In conclusion, my feeling is that the underground wires were damaged by lightning, even though it seems like a coincidence that the system worked before the incident. In order for the metal center pivot to become energized, the system would have to have a failure present to allow this to happen. The ground connection at the tower would have to be broken or disconnected. At the same time voltage from one of the ungrounded conductors would have to have come in contact with the metal frame and not blow a fuse. I saw no signs to indicate that this could have happened on this unit. Also, we should have been able to measure voltage at several different times in the above procedures.”

The three firms could not determine how the tower became energized. MIFACE postulates that direction of the electrical current was not from the tower, through the decedent, to the ground but the inverse – from the ground, through the decedent, to the tower. After consulting with a number of electrical engineers, another scenario for the electrocution has been developed. The hypothesis: the patch of earth where the decedent was standing was energized due to the directly buried, damaged, underground wiring. The decedent, while standing in a puddle of water on this energized patch of earth, contacted the grounded irrigation system. He became a path to ground and was fatally electrocuted.

MIFACE was able to review Firm B’s report, which was contained in the MIOSHA compliance file. MIFACE did not receive the permission of the decedent’s employer to contact the other electrical consultants investigating the incident.

CAUSE OF DEATH

The cause of death as listed on the death certificate was electrocution. The medical examiner noted that the decedent had multiple erythematous blistered lesions on anterior surface of left forearm up to 3/16 inches over a 3.5 x 31/2 inch area, consistent with thermal injury. Toxicology was negative for alcohol and prescription or illegal drugs.

RECOMMENDATIONS/DISCUSSION

- Ensure irrigation system wiring and grounding is continuous and in accordance with the appropriate American Society of Agricultural Engineers Standards and the National Electric Code.

The American Society of Agricultural Engineers (ASAE) has several standards that address wiring to a pivot irrigation system: Standard S362.2, "Wiring and Equipment for Electrically Driven or Controlled Irrigation Machines" and Standard S397.2 "Electrical Services and Equipment for Irrigation." The following sections of the National Electric Code (NEC) apply to electric drive center pivot irrigation systems:

1.) Article 250-51 Effective grounding.
2.) Article 250-114 Effective grounding.
3.) Article 310 Minimum size of conductors.
4.) Article 210-5 Color code for branch circuits.
5.) Article 430 Motors, motor circuits or controlled.
6.) Article 675 Irrigation machines.

ASAE Standard S362.2, which is voluntary, states in Section 5.7 that overcurrent protective devices shall be provided and sized in accordance with the requirements of the device or devices served but shall not exceed the current allowed by NFPA Standard No. 70, National Electrical Code for the conductors employed. The post inspection of the irrigation unit revealed that the very first disconnect switch feeding power to the pivots had 50-amp fuses, which were oversized. Proper grounding of the irrigation system is one of the keys to preventing injury. As detailed in the *Missouri Extension Bulletin*, to be ensured of a safe system, the farmer, dealer and installer should insist that:

- Grounding is in accord with NEC Section 675-9, which says a separate non-current-carrying equipment grounding conductor needs to be run with all circuit conductors..
- Ground rods should be driven as indicated in Figure 1. Steel or iron rods should be at least 5/8 inch in diameter. Non-ferrous rods should be at least 1/2 inch in diameter. All rods must be driven at least 8 feet deep.
- Grounding conductors must be metallically bonded to the ground at the source of electrical supply (Figure 1).
- All metal enclosures, equipment and grounds must be connected to the grounding conductor. Also bond to the well casing if it is metal.

- Farmers should implement an electrical inspection program for irrigation equipment at the beginning of each season that includes periodic inspections of all system components throughout the growing season. This inspection should include checking the integrity of the underground wiring associated with the system.

To ensure the safety and reliability of the irrigation system, Reinke (and MIFACE) recommend the irrigation system's underground electrical (and mechanical) inspection be performed at the beginning of the growing season and periodically throughout the growing season. The reliability of the irrigation system depends upon good preventive maintenance. Reinke maintains the following warning on their Irrigation System Maintenance website: ***WARNING!*** *DO NOT attempt to perform any maintenance procedures until the Reinke Main Control Panel Disconnect*

Switch and all Pump Disconnect Switches are locked in the "OFF" position. Electrical component trouble-shooting and replacement should be performed by a certified Reinke Service Technician to ensure built-in safety features remain intact. Replace all Protective Guards and Shields before restoring power to the System.

The decedent's employer did not check the system's electrical system, including the underground wiring prior to or during the growing season. Much of the underground wiring was old and its condition questionable. It is unknown whether a check of loss of voltage would have been identified which may have caused the farmer to dig up the old wiring or check the electrical panels to note the fuse issue or other electrical issues. MIFACE recommends that at least one time during the growing season the integrity of the electrical system for the irrigation units be determined to identify electrical issues early. The only way to detect it is to use an insulation tester on the feeder regularly.

- When installing new underground wiring for irrigation systems, farmers should consider installing the wiring in PVC conduit to protect the wiring insulation.

It is unknown to what depth the old, directly buried, damaged wiring was buried in the field and to what depth the new wiring was directly buried. According to Firm B's report there were "multiple locations where the underground wires had been damaged". MIFACE does not know the location of these damaged wires. Also unknown is the experience of the three investigators regarding the identification of "lightning damage" to the wiring. It is unknown if there are pictures of the "lightning damage" on the wiring.

Frost heaving and stones in the soil, in addition to lightning, can damage wiring insulation causing the wire to leak electrical current. Lighting damages the cable insulation by creating many little pinholes, which are literally invisible and will only become apparent once they have existed long enough for current flow to the earth to damage the insulation enough to enlarge the pinholes. Copper wire can sustain this kind of damage a longer time. Aluminum wiring will deteriorate more rapidly and the cable will burn through in months. Any ragged tear in the insulation is due to a shovel cut or frost heaving around gravelly fill, not lightning.

If wiring was buried in PVC conduit, the insulation would be protected from frost heaving and stones, in addition to providing limited protection from lightning strikes.

- General agricultural workers should be prohibited from working in a field area which is under active irrigation; however, manufacturing and trained service and maintenance workers may have to do work with operational irrigation units.

Although cooling for workers, MIFACE recommends that general agricultural workers do not perform work activities in an area under active irrigation. In addition to the unanticipated electrical issues which may be present (as noted in this fatality), there are hazards such as slips, trips and falls due to slippery conditions. Trained individuals performing service or maintenance may need to have the unit operational.

- In areas of high levels of lightning activity, farmers should consult with the irrigation system manufacturer to determine if installing lightning arrestors on the central pivot will provide additional protection for their equipment.

American Society of Agricultural Engineers (ASAE) Standard EP381.1– Specifications for Lightning Protection contains safety recommendations for lightning protection on farms. ASAE safety standards are not laws. They are recommended voluntary standards that can be considered "best safety management practices".

According to Rain Bird Winter 2000 Technical Newsletter, "irrigation systems are particularly susceptible to lightning strikes because they have large amounts of wire buried in the ground that can attract lightning". Additionally, they are often the high point in the field and present the shortest path to ground for the lightning. Farmers should consult with the irrigation system manufacturer to determine if installing lightning arrestors on the central pivot will provide additional protection for their equipment.

REFERENCES

MIOSHA standards cited in this report may be found at and downloaded from the MIOSHA, Michigan Department of Licensing and Regulatory Affairs (LARA) website at: www.michigan.gov/mioshastandards. MIOSHA standards are available for a fee by writing to: Michigan Department of Licensing and Regulatory Affairs, MIOSHA Standards Section, P.O. Box 30643, Lansing, Michigan 48909-8143 or calling (517) 322-1845.

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